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FIG 1

Inventor: Ando, et al
 Docket No.: 12052.33USD2
 Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
 COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
 OF COLD-FORGING
 Attorney Name: Curtis B. Hamre
 Phone No.: (612) 336-4722
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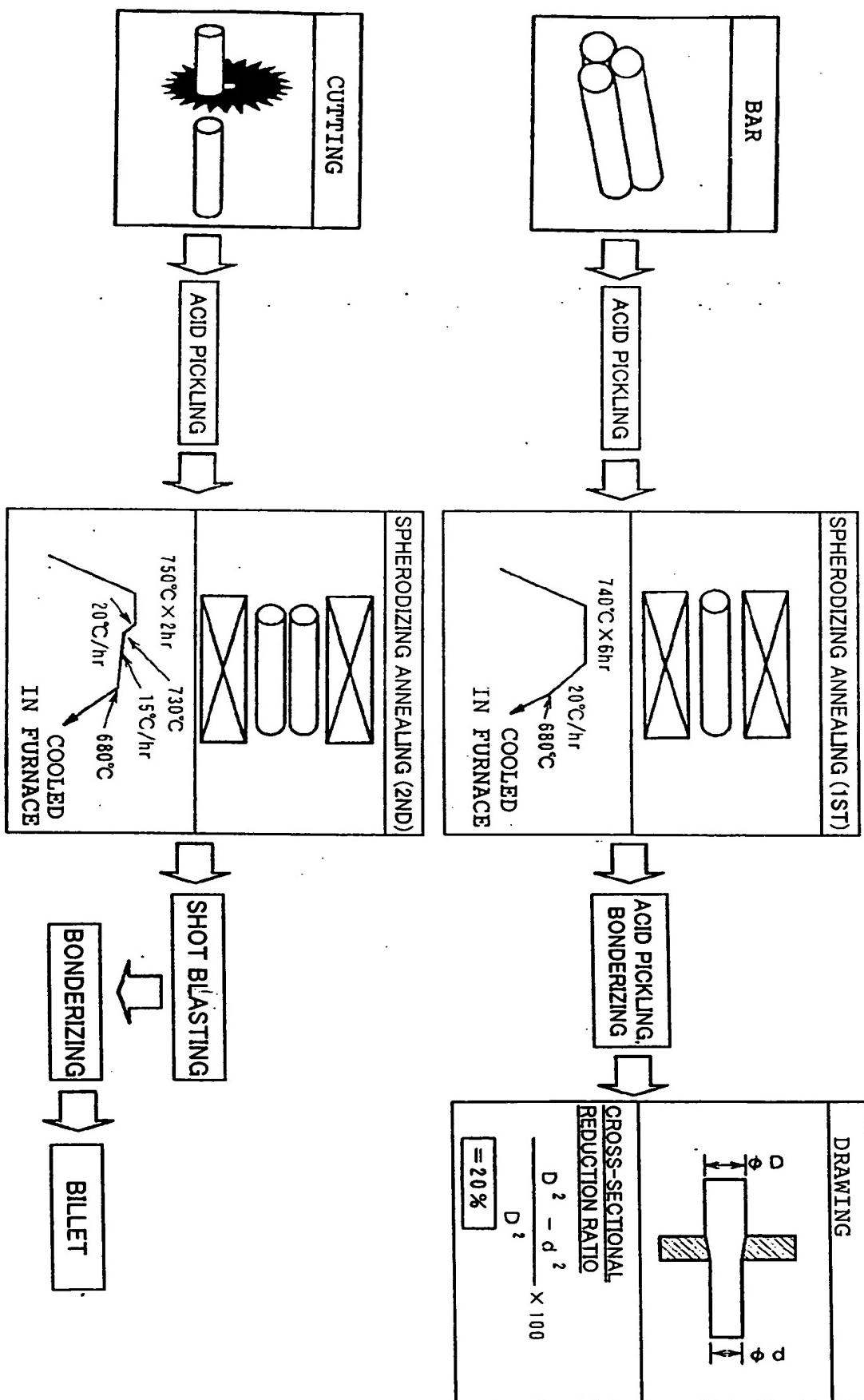
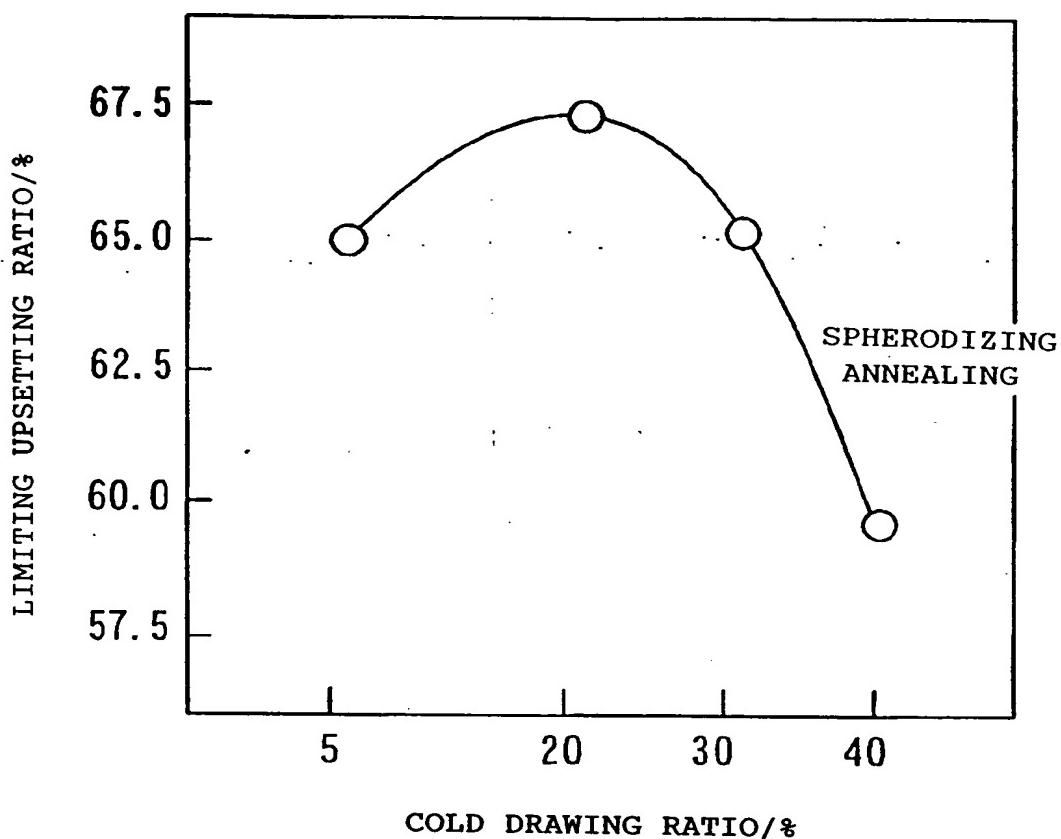
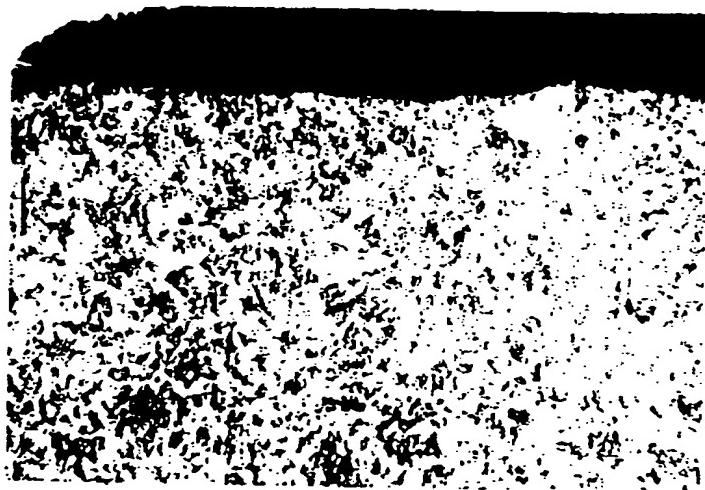


FIG. 2

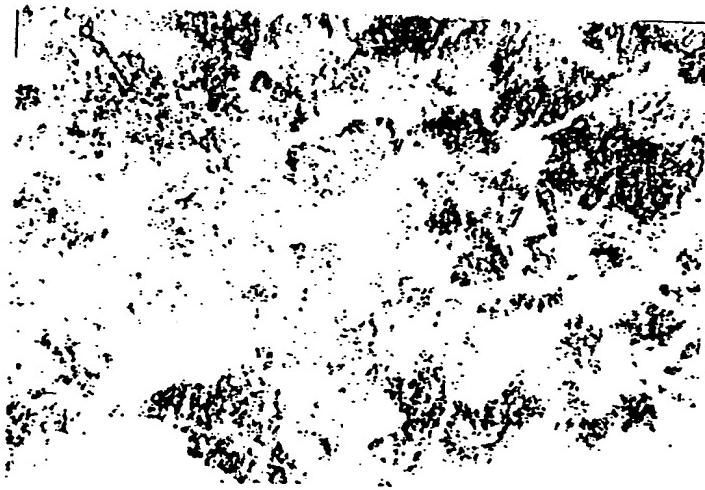


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FIG. 3



(a)



(b)

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FIG. 4



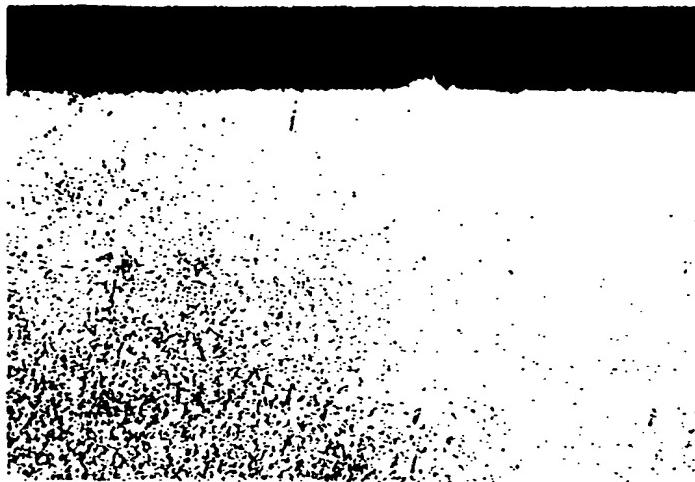
(a)



(b)

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Docket No.: 12052.33USD2
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FIG. 5



(a)



(b)

FIG. 6

(A) MATERIAL 1

ASPECT RATIO = 506 %



(B) MATERIAL 2

ASPECT RATIO = 347 %



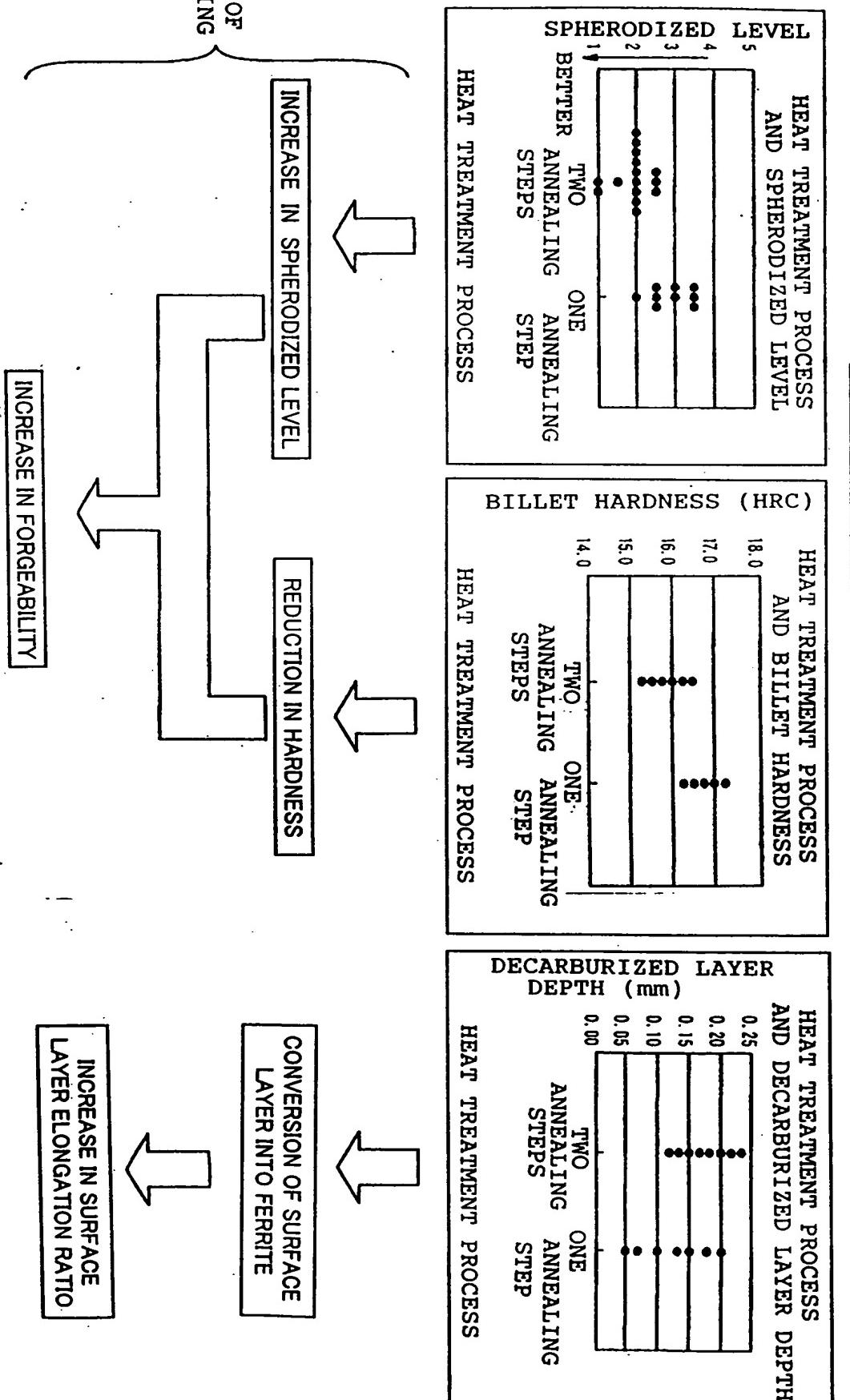
(C) MATERIAL 3

ASPECT RATIO = 300 %



FIG. 7

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FIG. 8

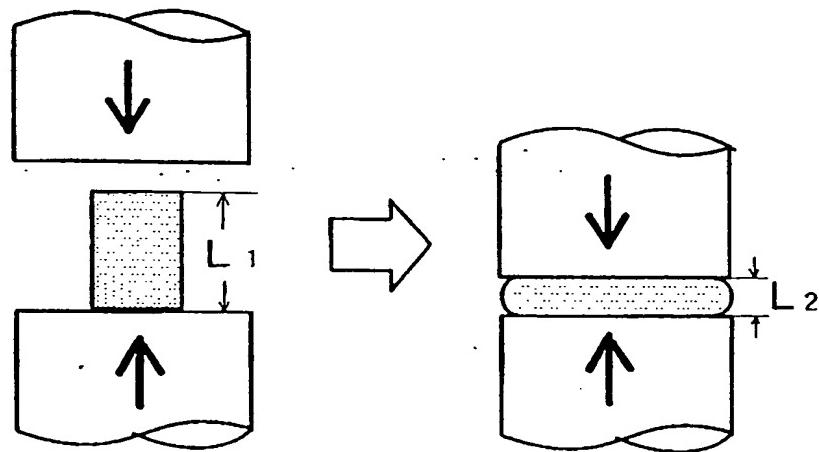


FIG. 9

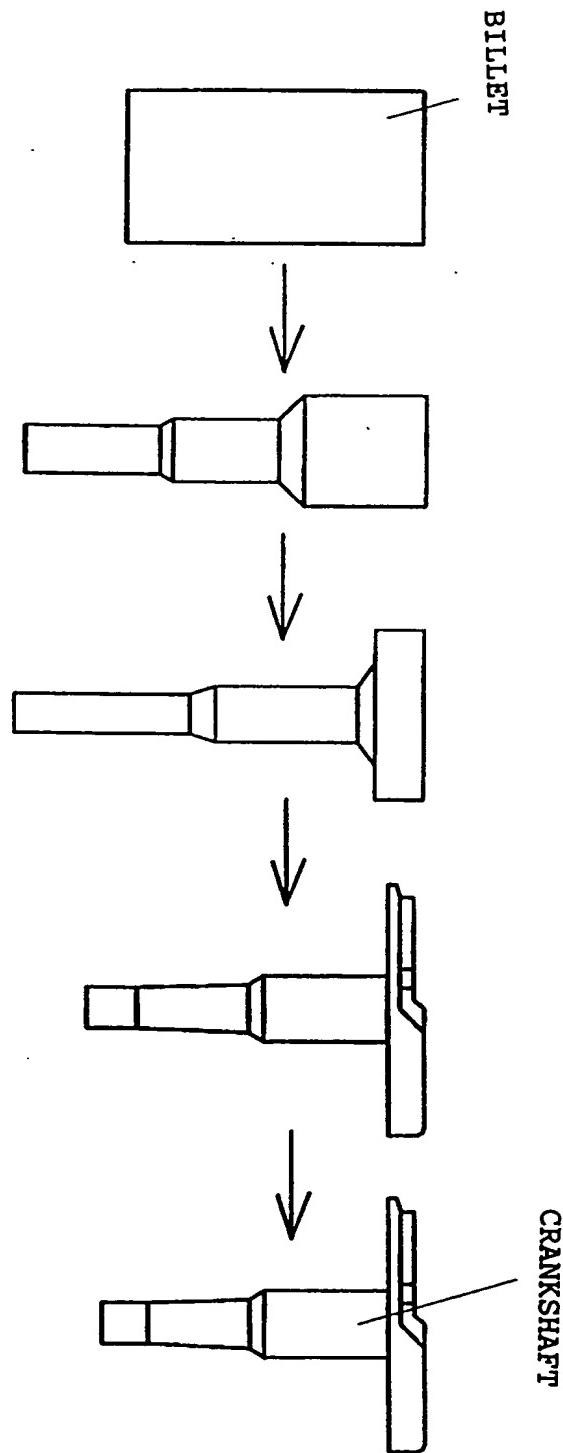


FIG. 10

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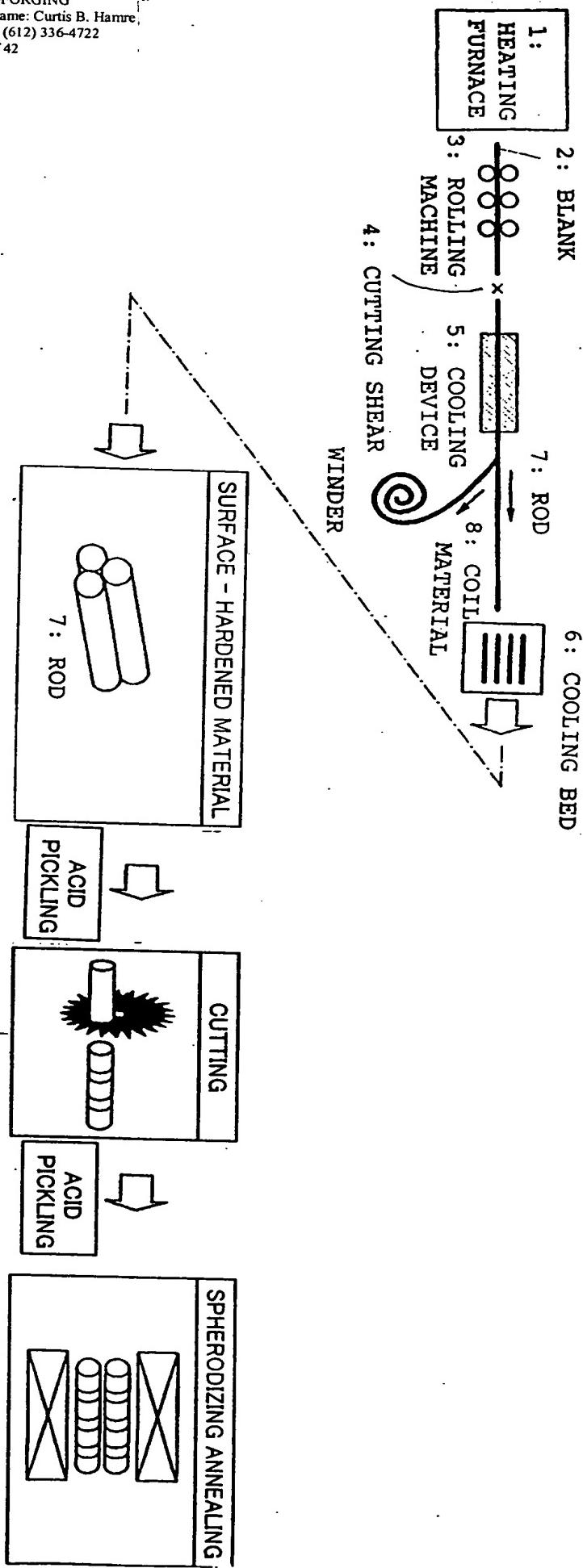
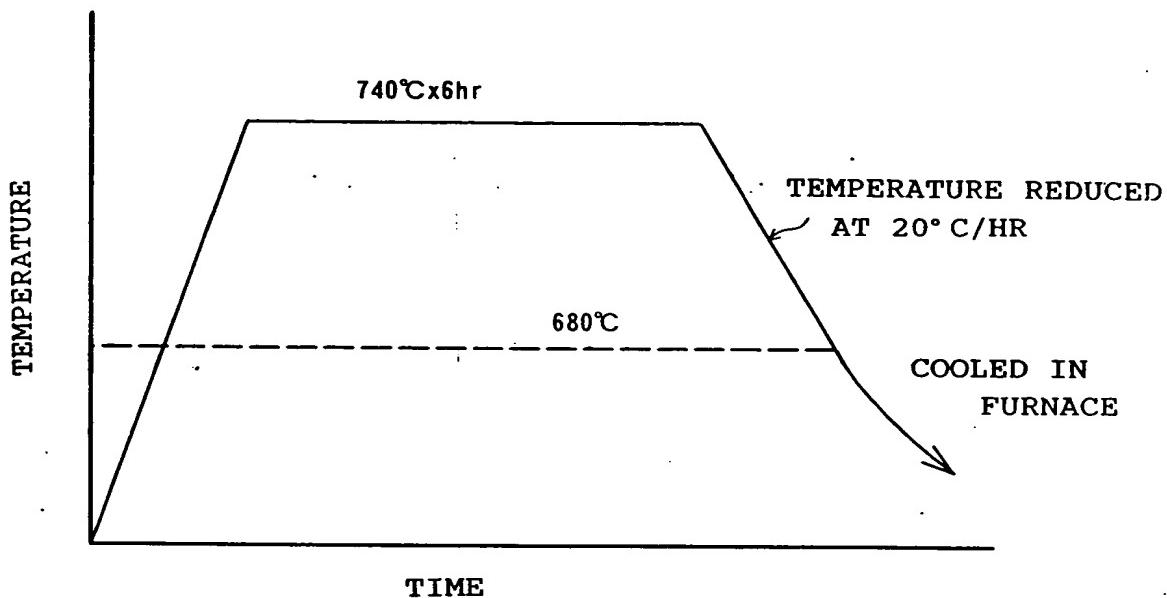
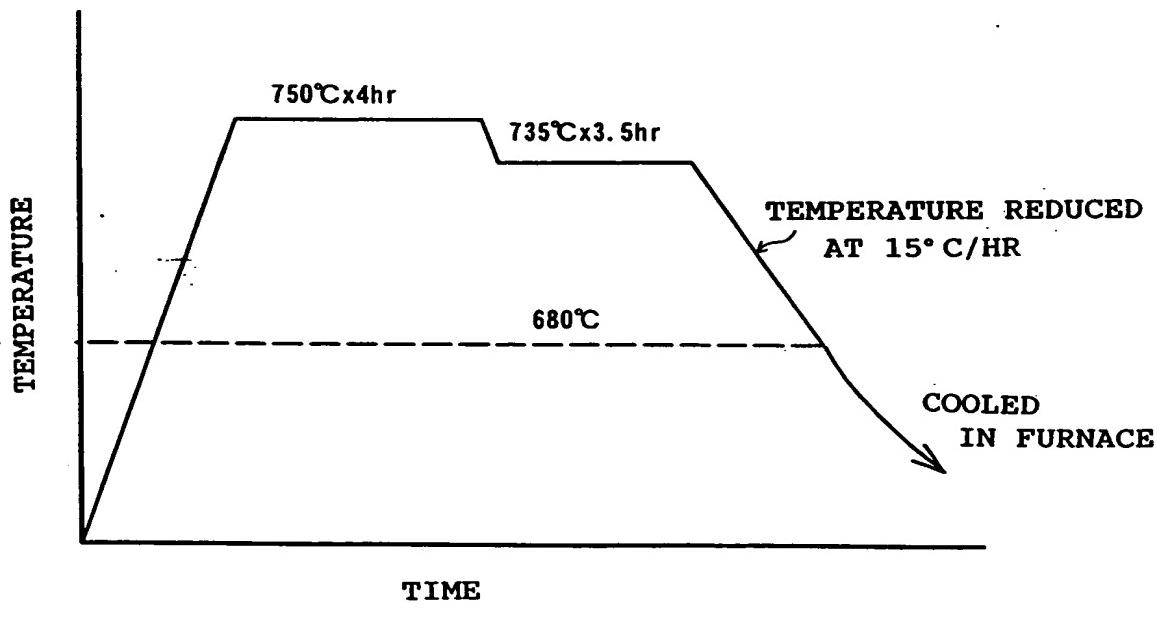


FIG. 11

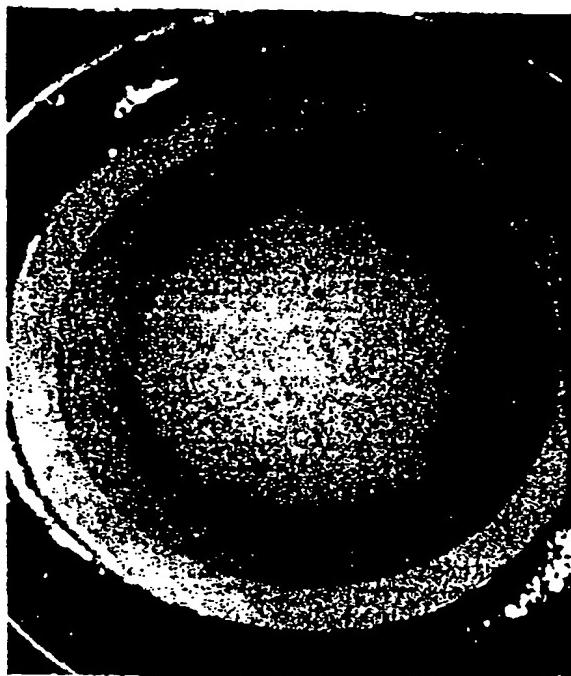


(a)

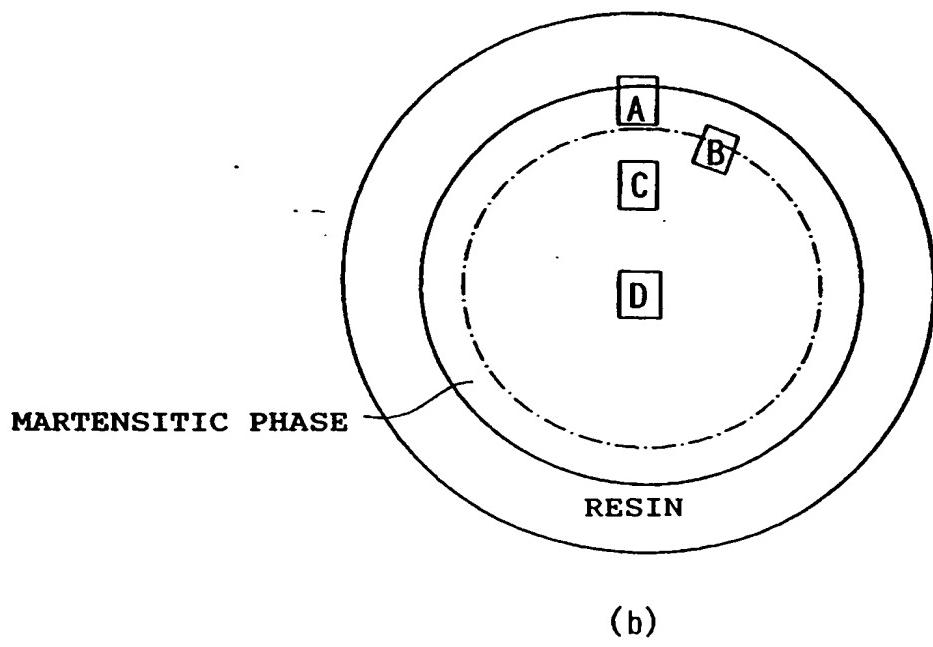


(b)

FIG. 12



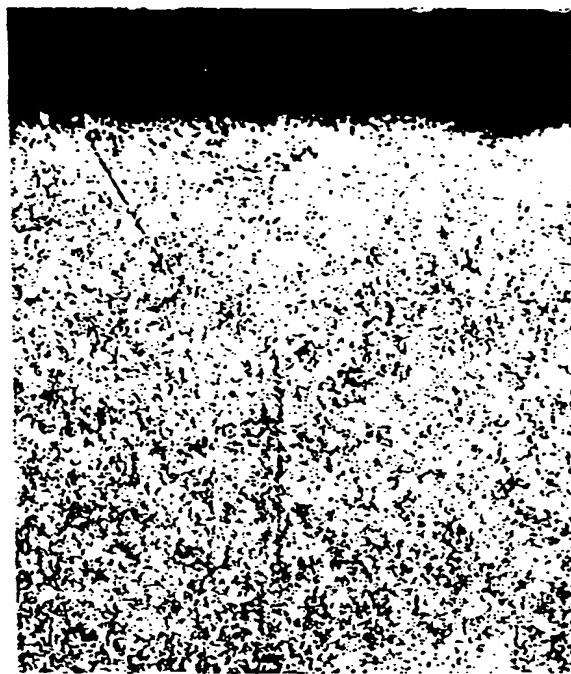
MARTENSITIC MATERIAL
(a) PRIOR TO SPHERODIZING ANNEALING
 $\times 2.1$



(b)

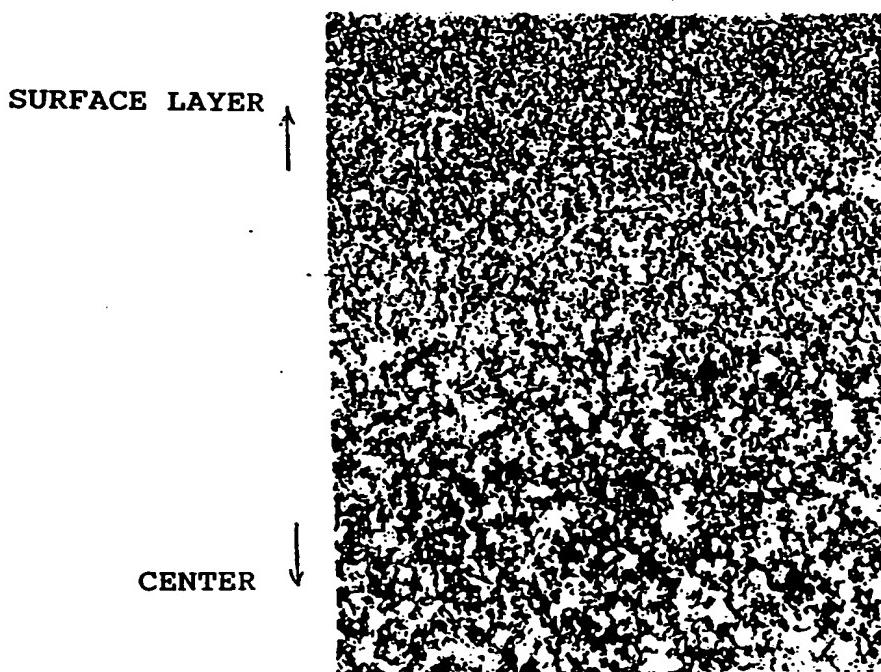
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FIG. 13



PRIOR TO SPHERODIZING ANNEALING
SURFACE LAYER $\times 100$

FIG. 14



MARTENSITIC
PHASE
↑
↓
INTERMEDIATE
LAYER

PRIOR TO SPHERODIZING ANNEALING
SURFACE LAYER AND INTERMEDIATE LAYER $\times 200$

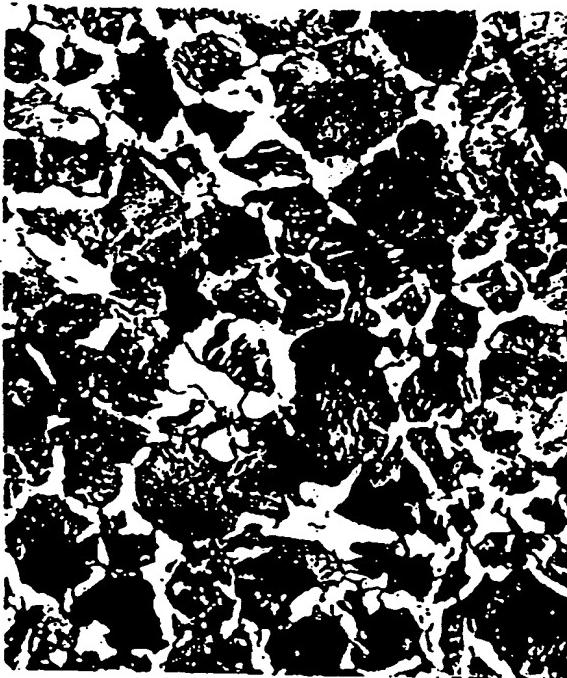
Inventor: Ando, et al
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FIG. 15



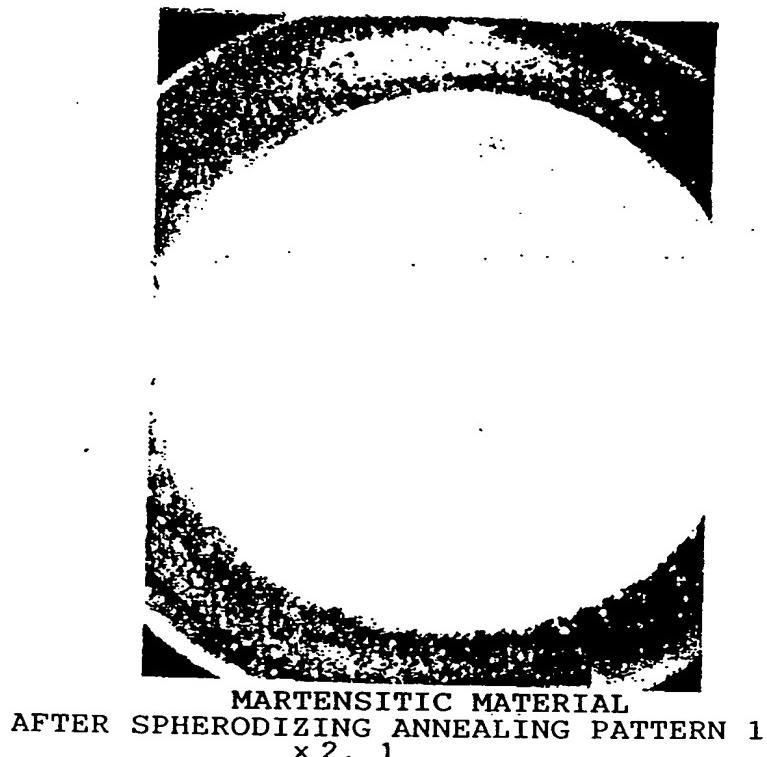
PRIOR TO SPHERODIZING ANNEALING
1/2 R PART \times 400

FIG. 16

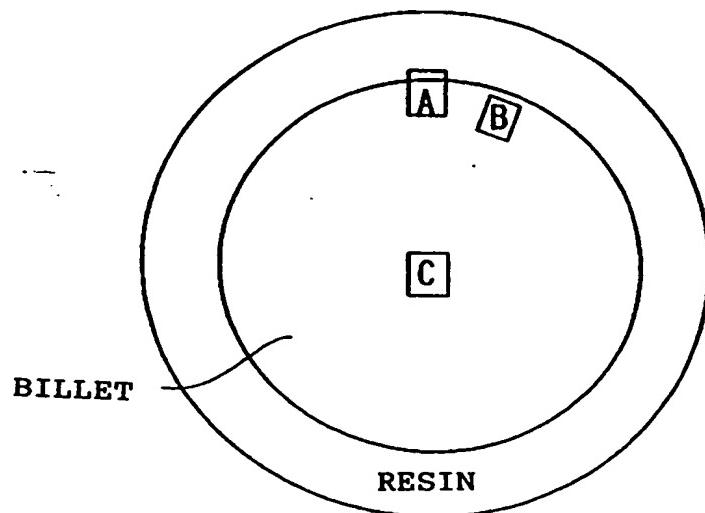


PRIOR TO SPHERODIZING ANNEALING
CENTRAL PART \times 400

FIG. 17



(a)



(b)

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Docket No.: 12052.33USD2

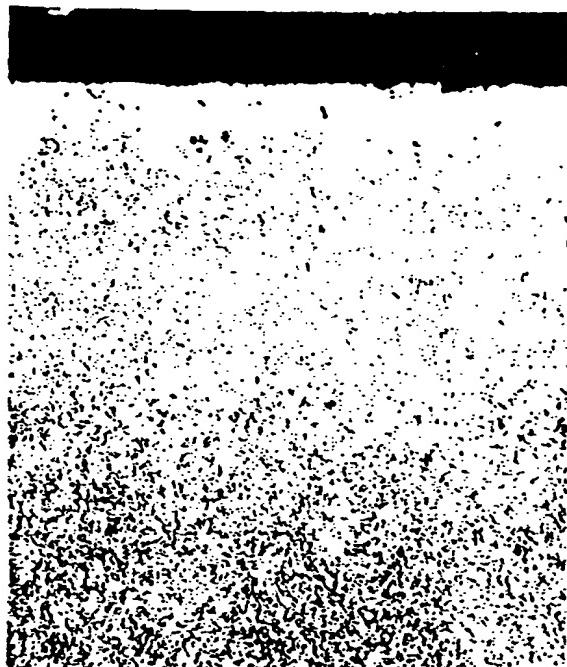
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COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
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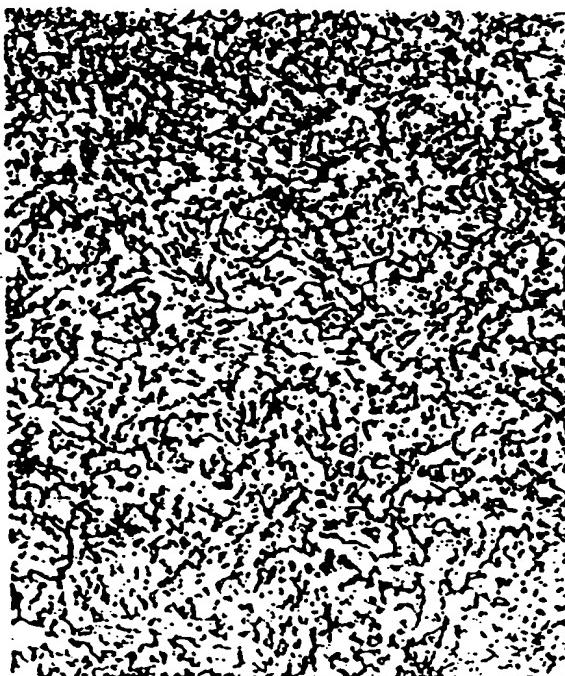
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FIG. 18



AFTER SPHERODIZING ANNEALING PATTERN 1
SURFACE LAYER × 100

FIG. 19



AFTER SPHERODIZING ANNEALING PATTERN 1
SURFACE LAYER × 400

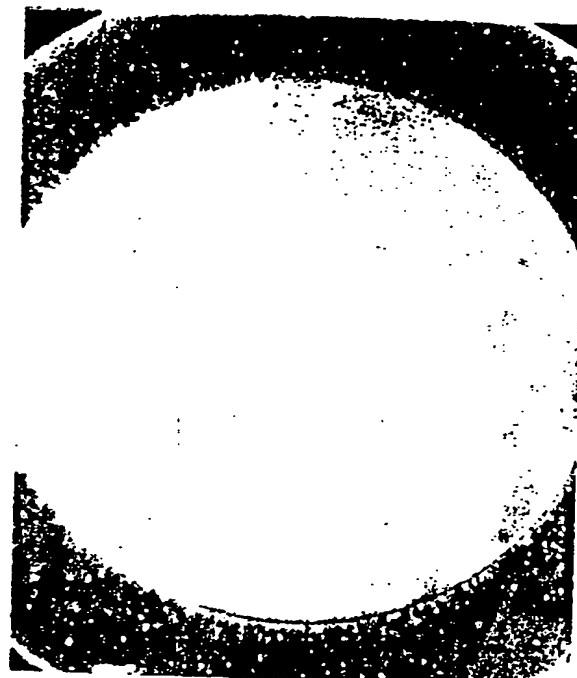
Inventor: Ando, et al
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FIG. 20



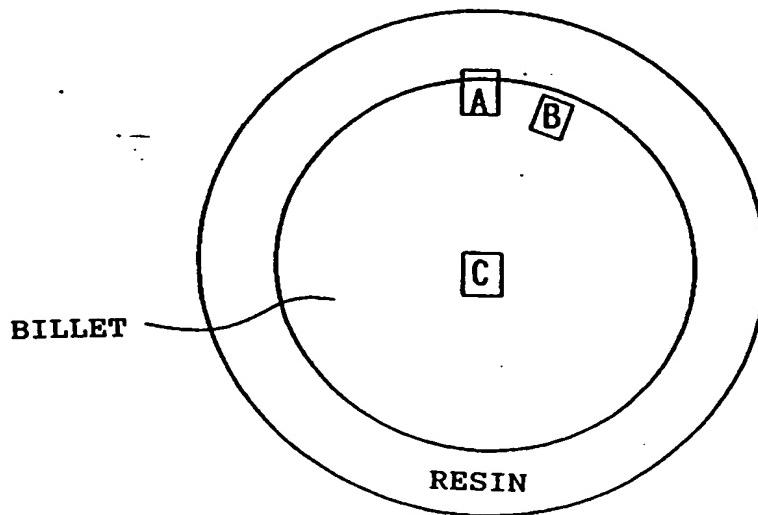
AFTER SPHERODIZING ANNEALING PATTERN 1
1/2 R PART × 400

FIG. 21



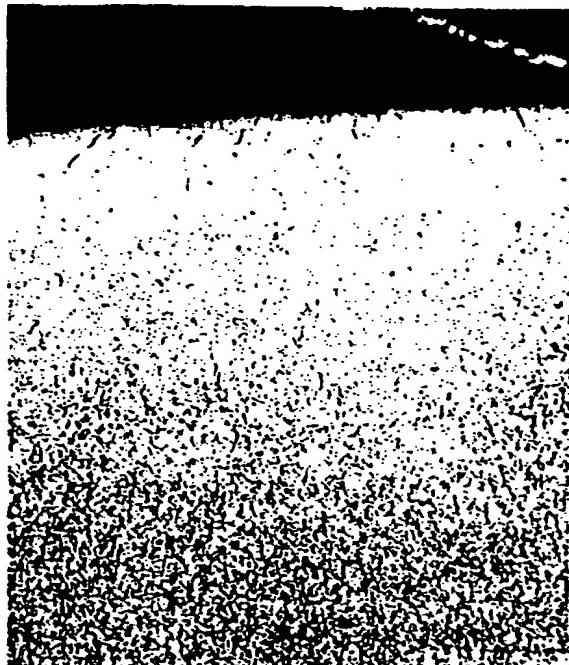
MARTENSITIC MATERIAL
AFTER SPHERODIZING ANNEALING PATTERN 2
 $\times 2.1$

(a)



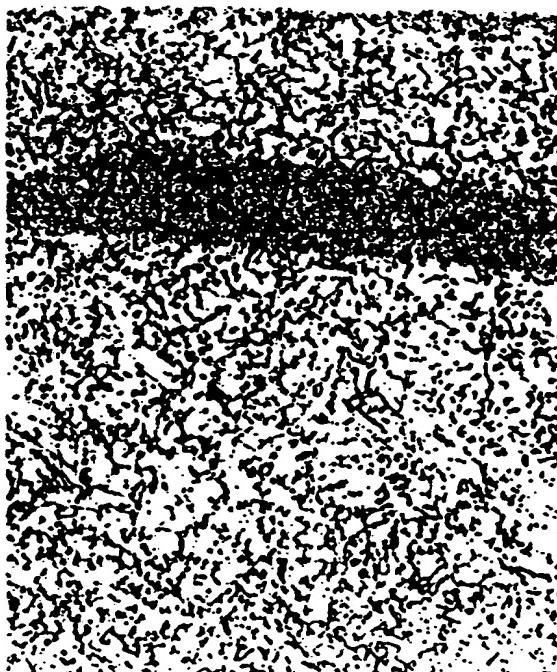
(b)

FIG. 22



AFTER SPHERODIZING ANNEALING PATTERN 2
SURFACE LAYER × 100

FIG. 23



AFTER SPHERODIZING ANNEALING PATTERN 2
SURFACE LAYER × 400

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FIG. 24



AFTER SPHERODIZING ANNEALING PATTERN 2
1/2 R PART × 400

FIG. 25

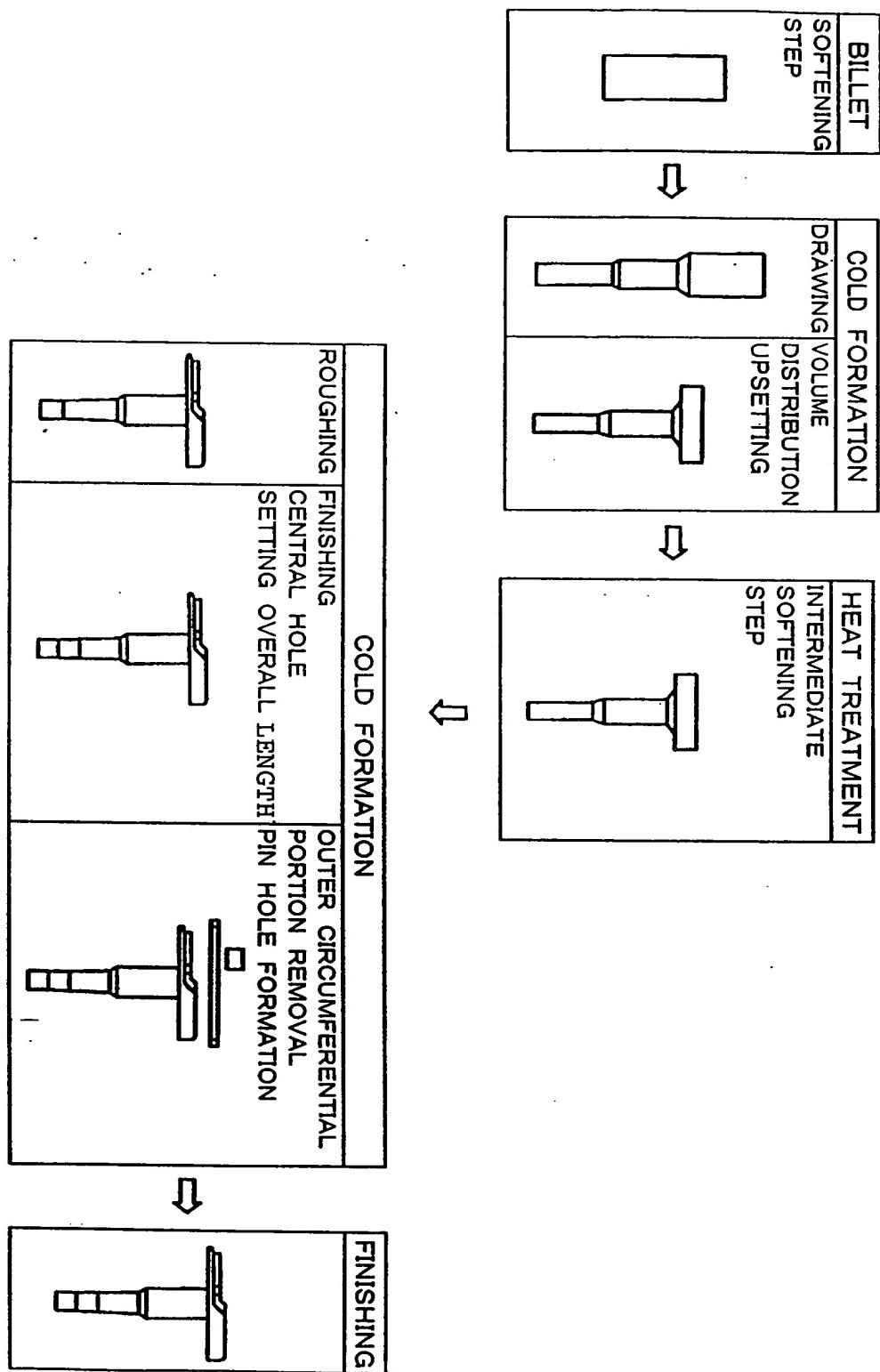
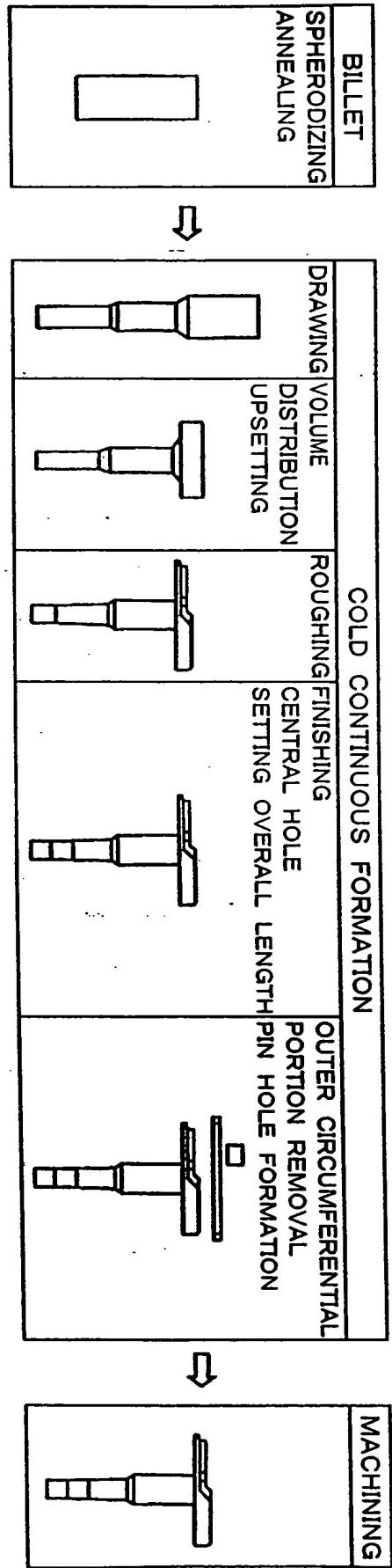


FIG. 26

Inventor: Ando, et al
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FIG. 27

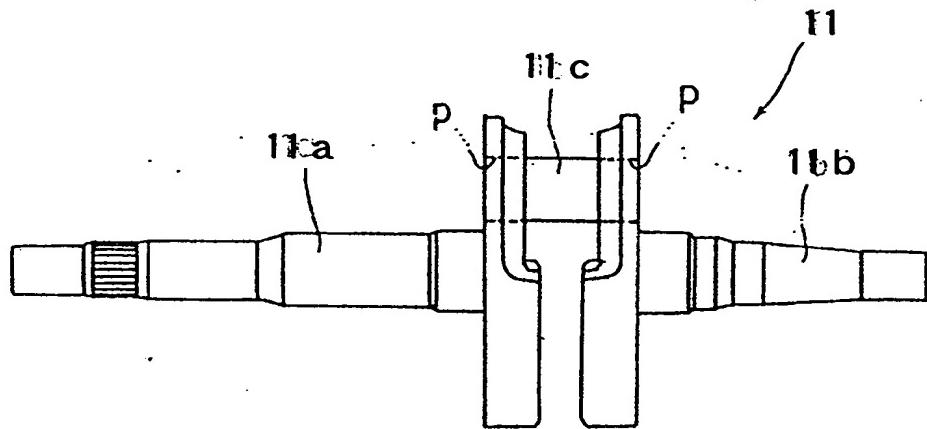


FIG. 28

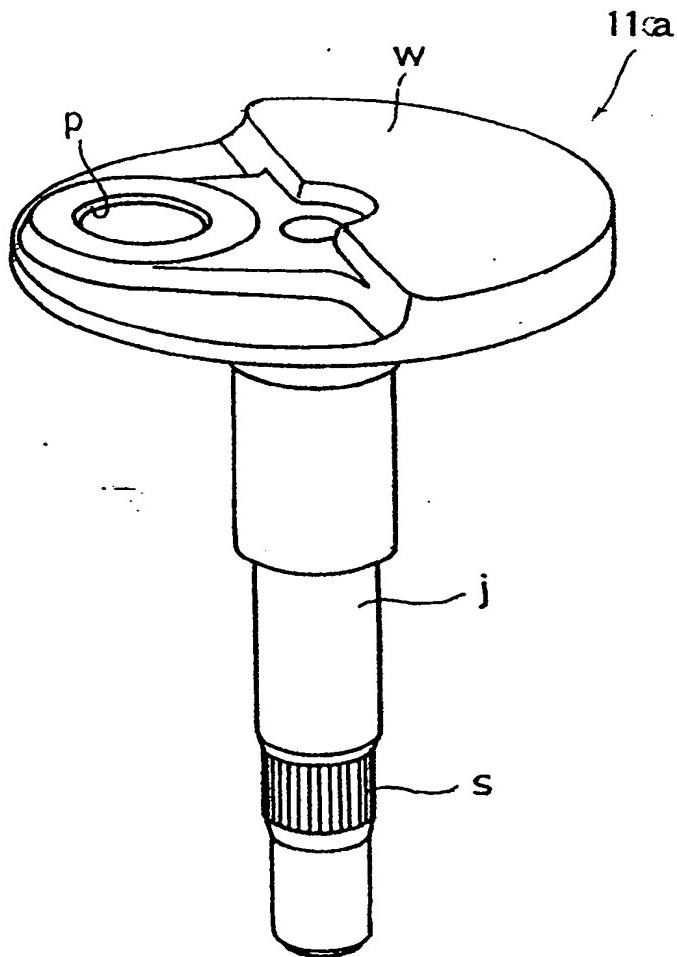


FIG. 29

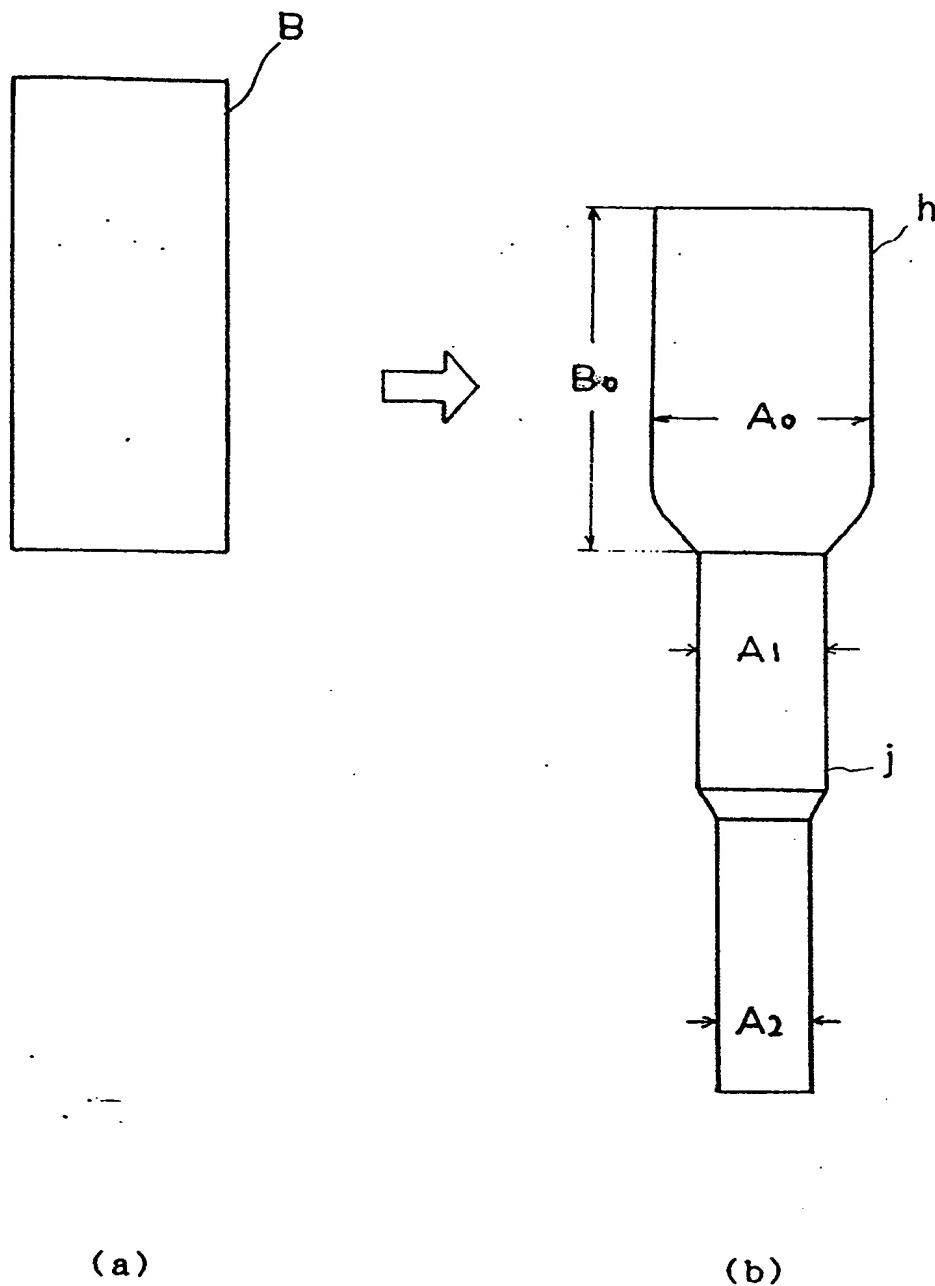
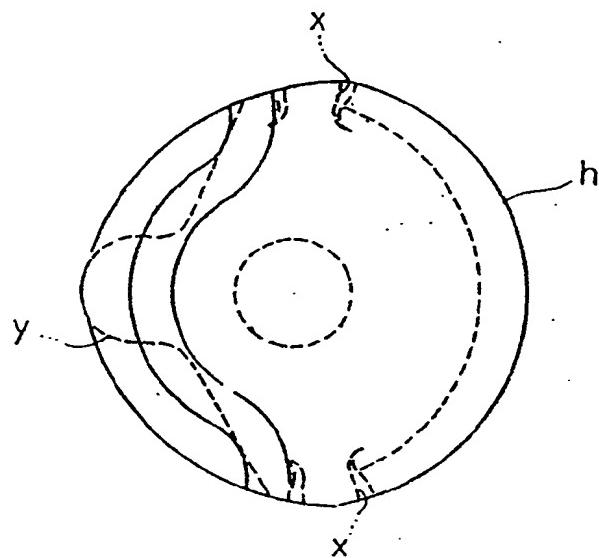
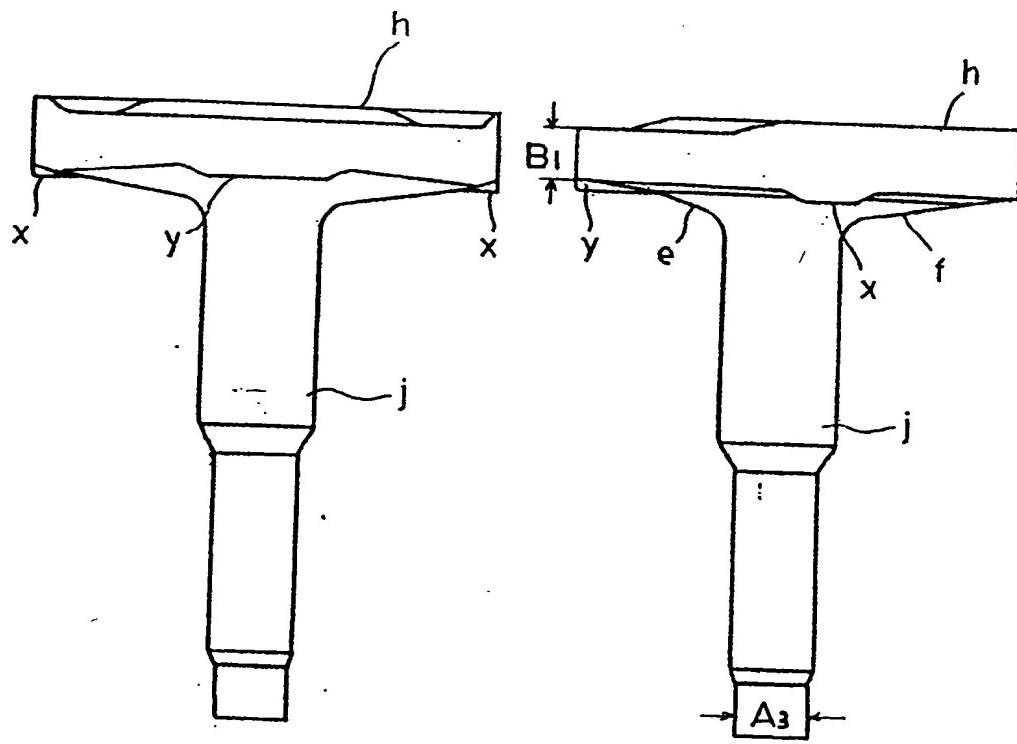


FIG. 30



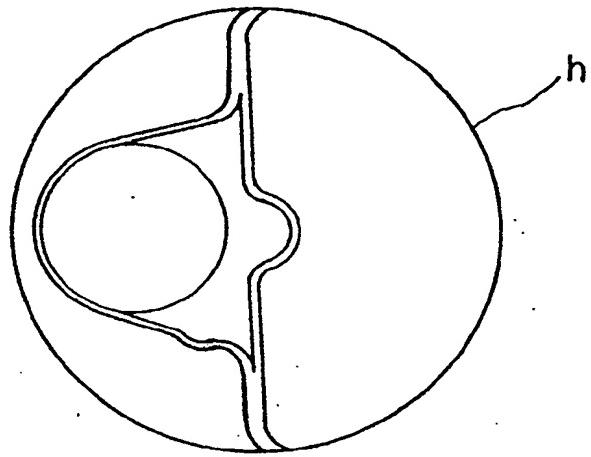
(a)



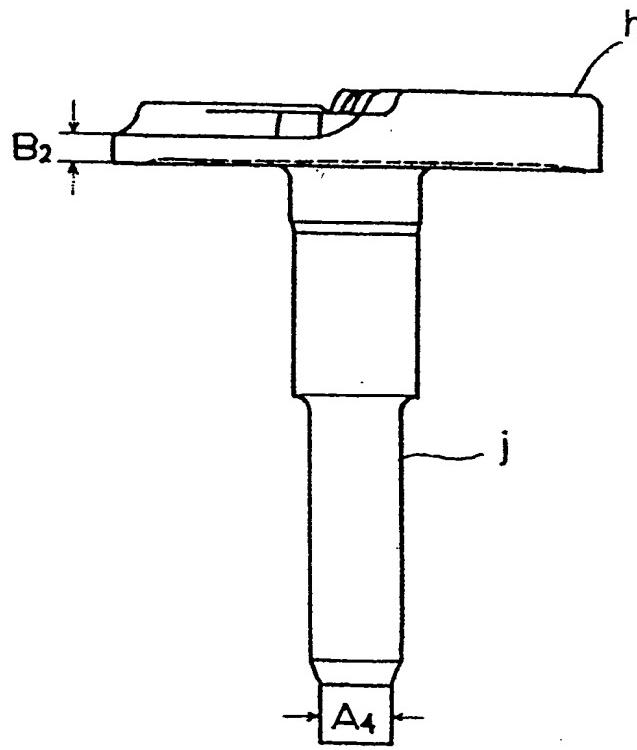
(b)

(c)

FIG. 31

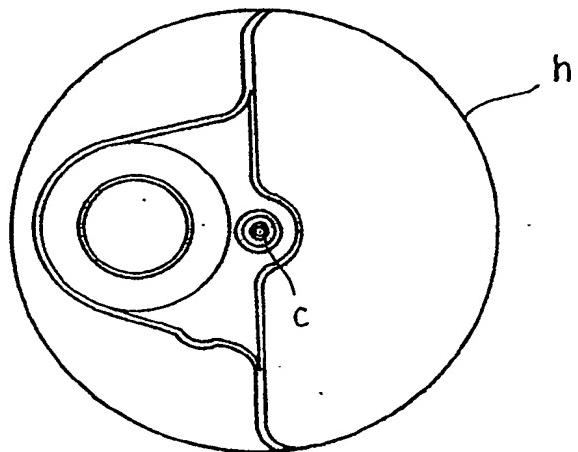


(a)

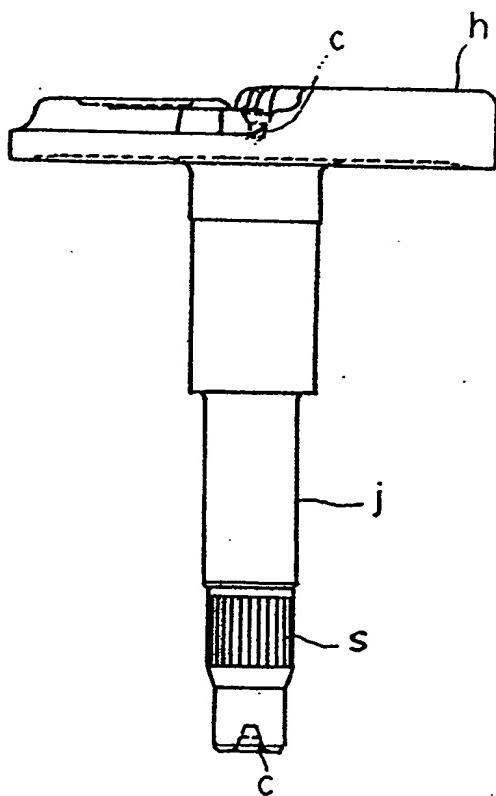


(b)

FIG. 32

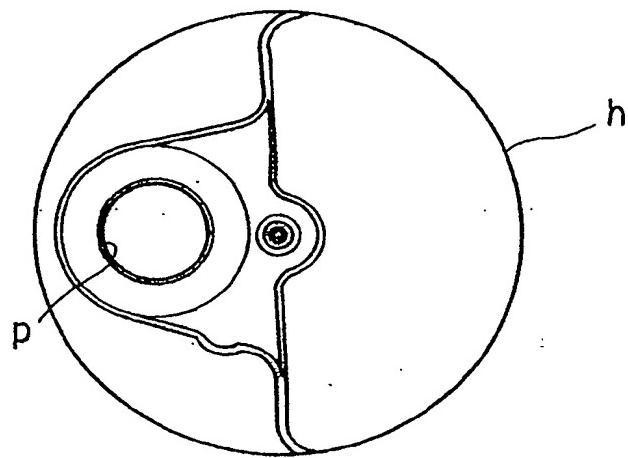


(a)

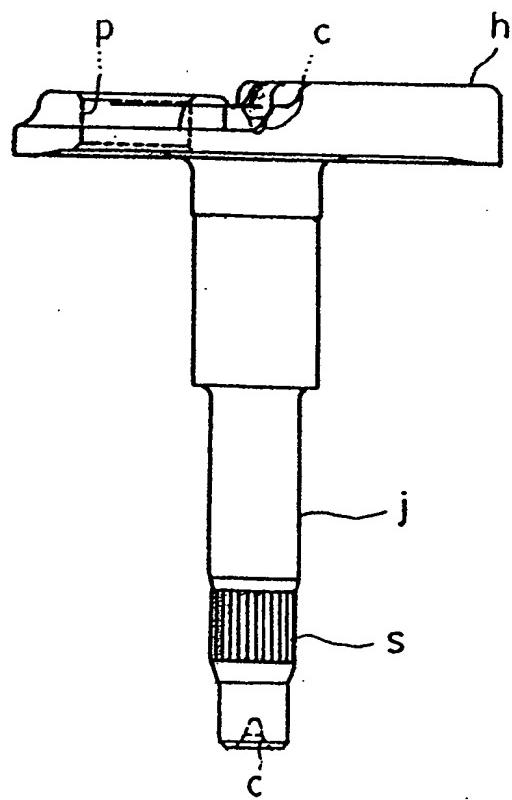


(b)

FIG. 33



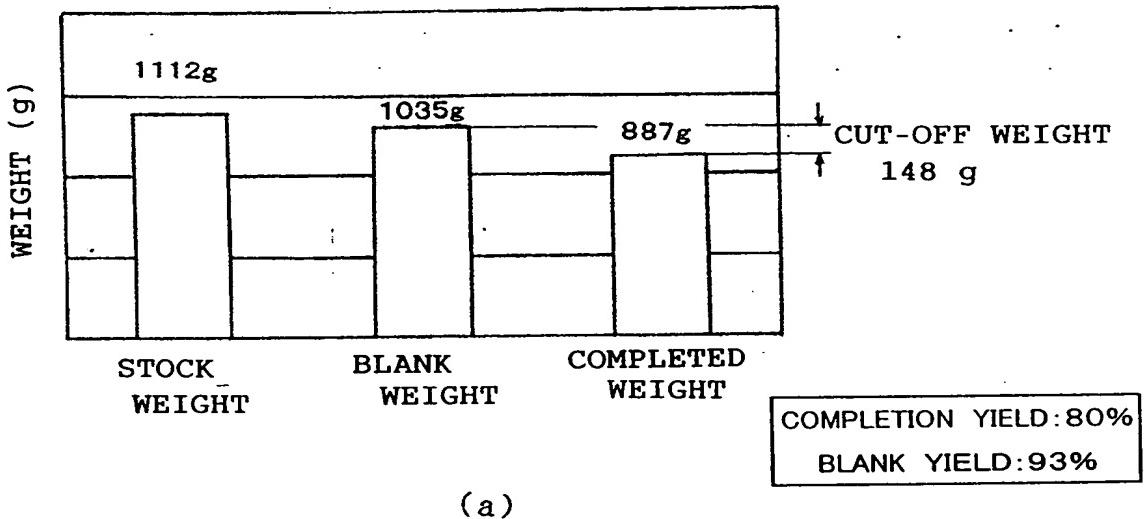
(a)



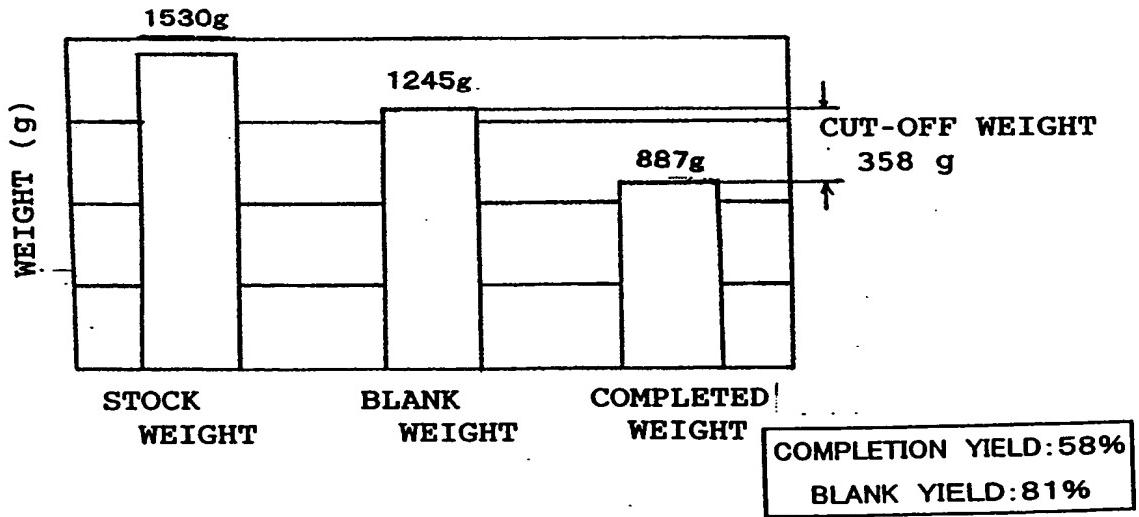
(b)

FIG. 34

(INVENTIVE COLD-FORGING METHOD)



(CONVENTIONAL COLD-FORGING METHOD)



(b)

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FIG. 35

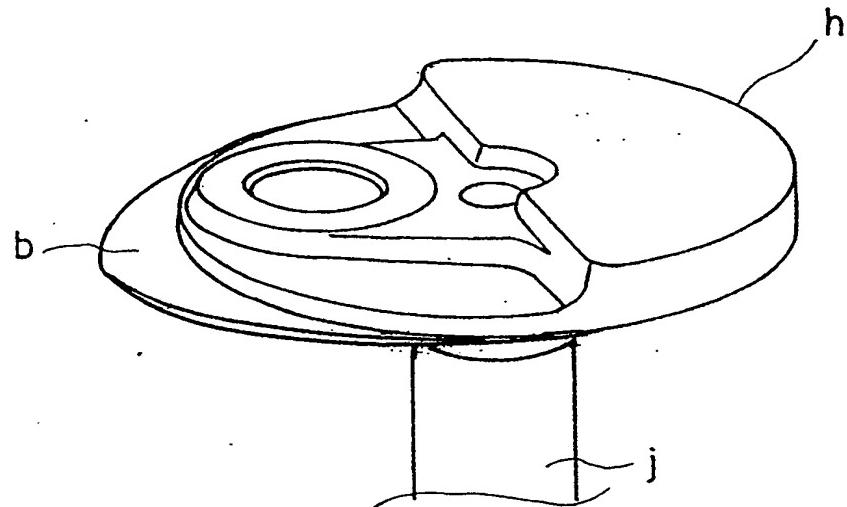
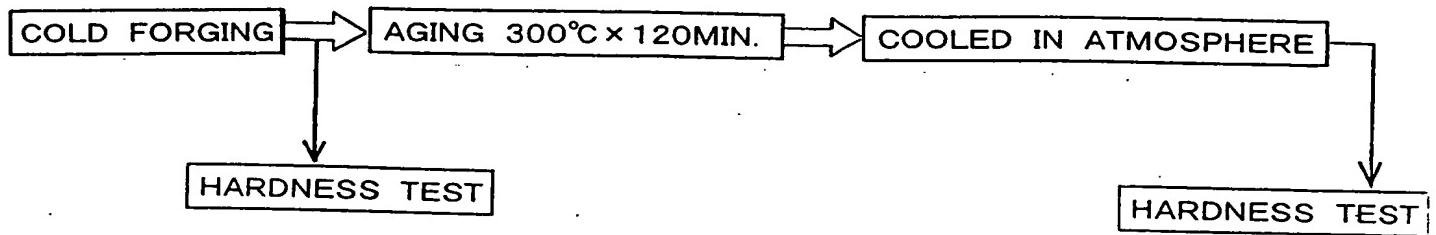
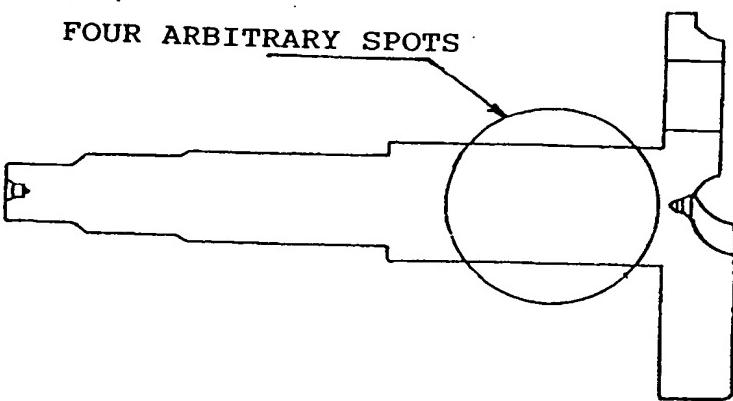


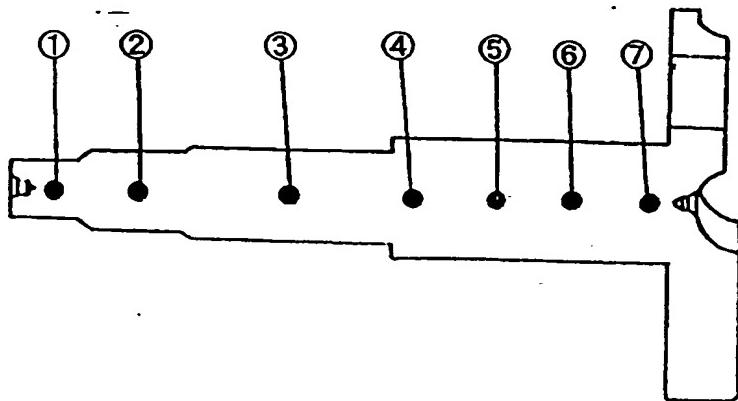
FIG. 36



(a)



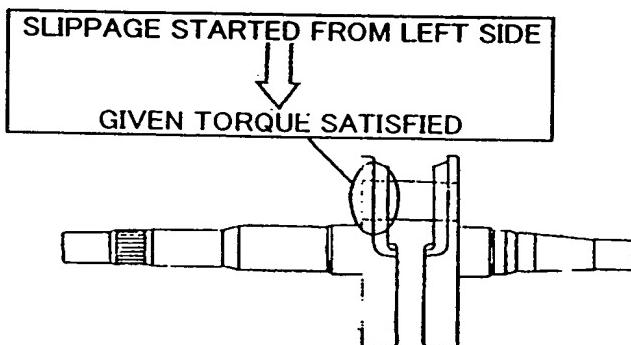
(b)



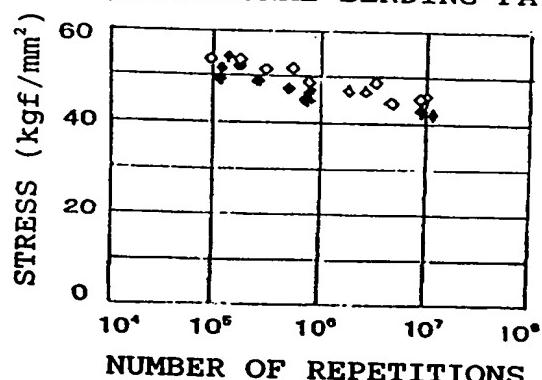
(c)

FIG. 37

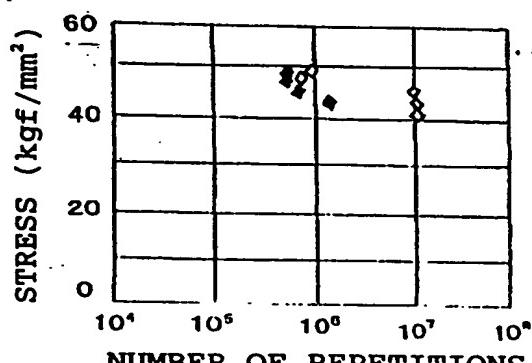
SLIP TORQUE



S - N CURVE (ROTATIONAL BENDING FATIGUE TEST)

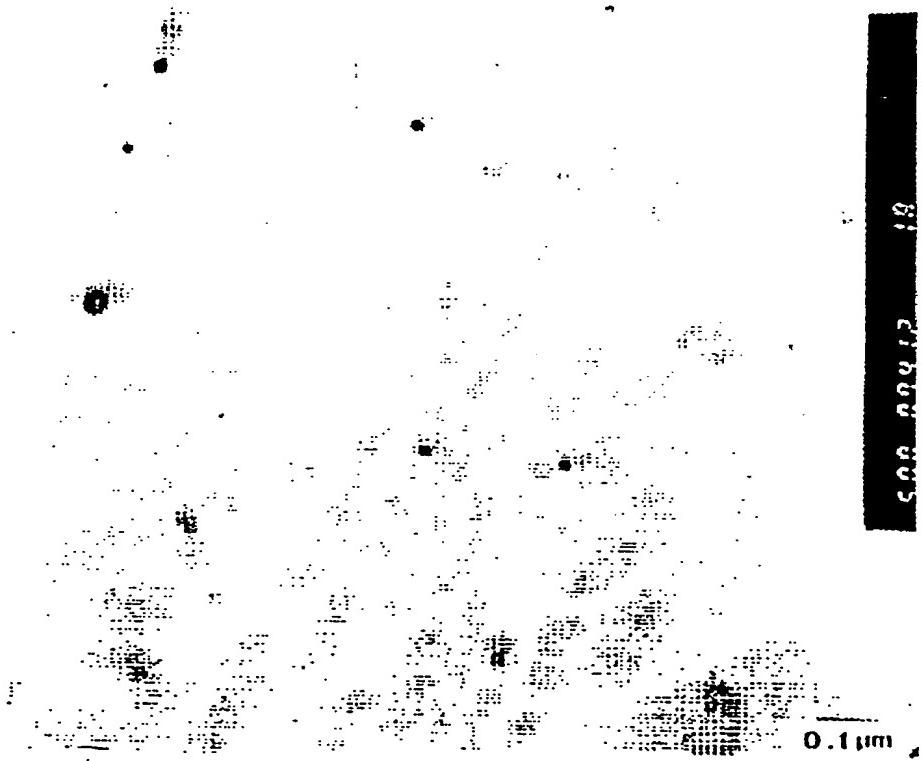


S - N CURVE (SOLID BENDING FATIGUE TEST)



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FIG. 38



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FIG. 39



FIG. 40

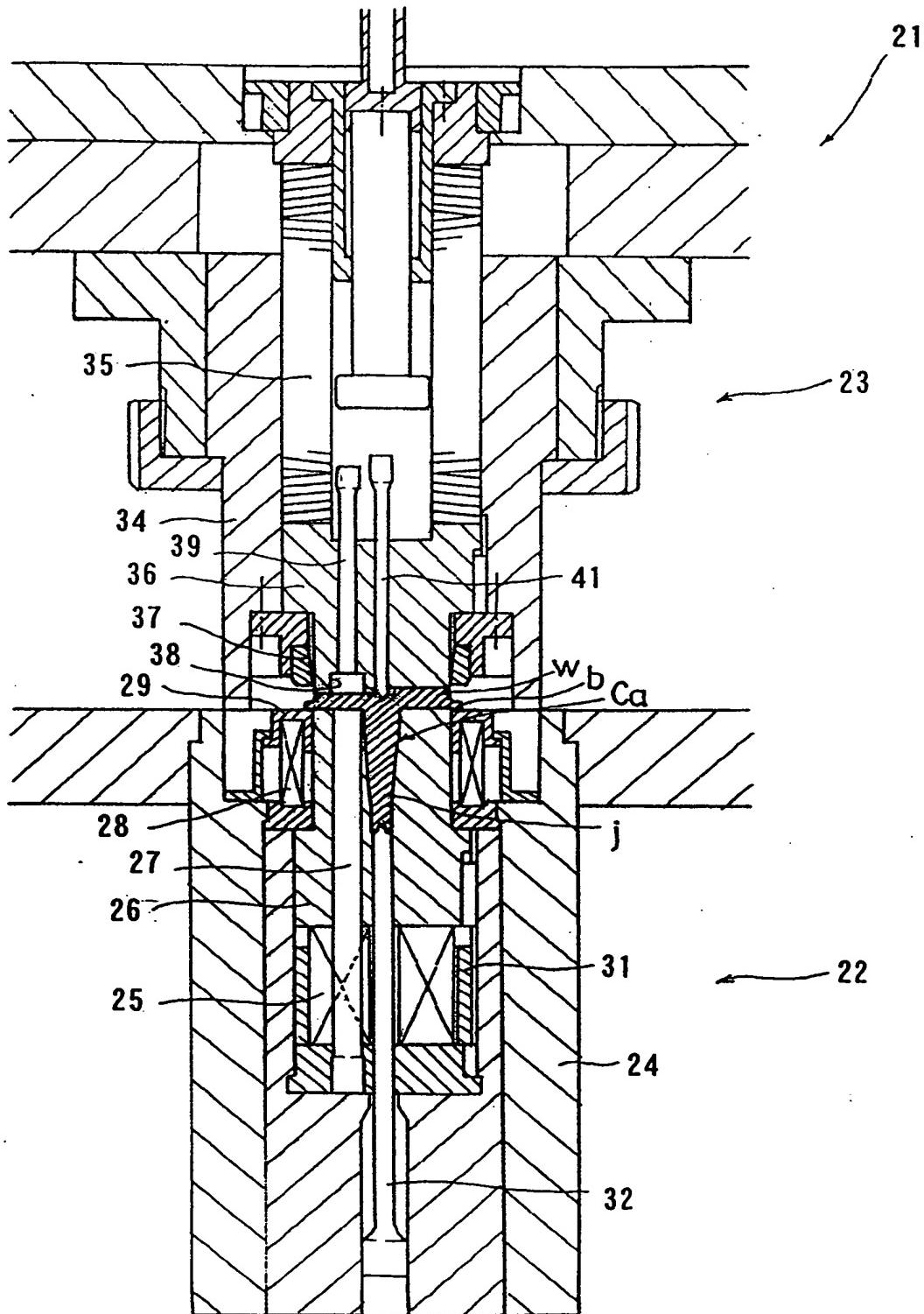


FIG. 41

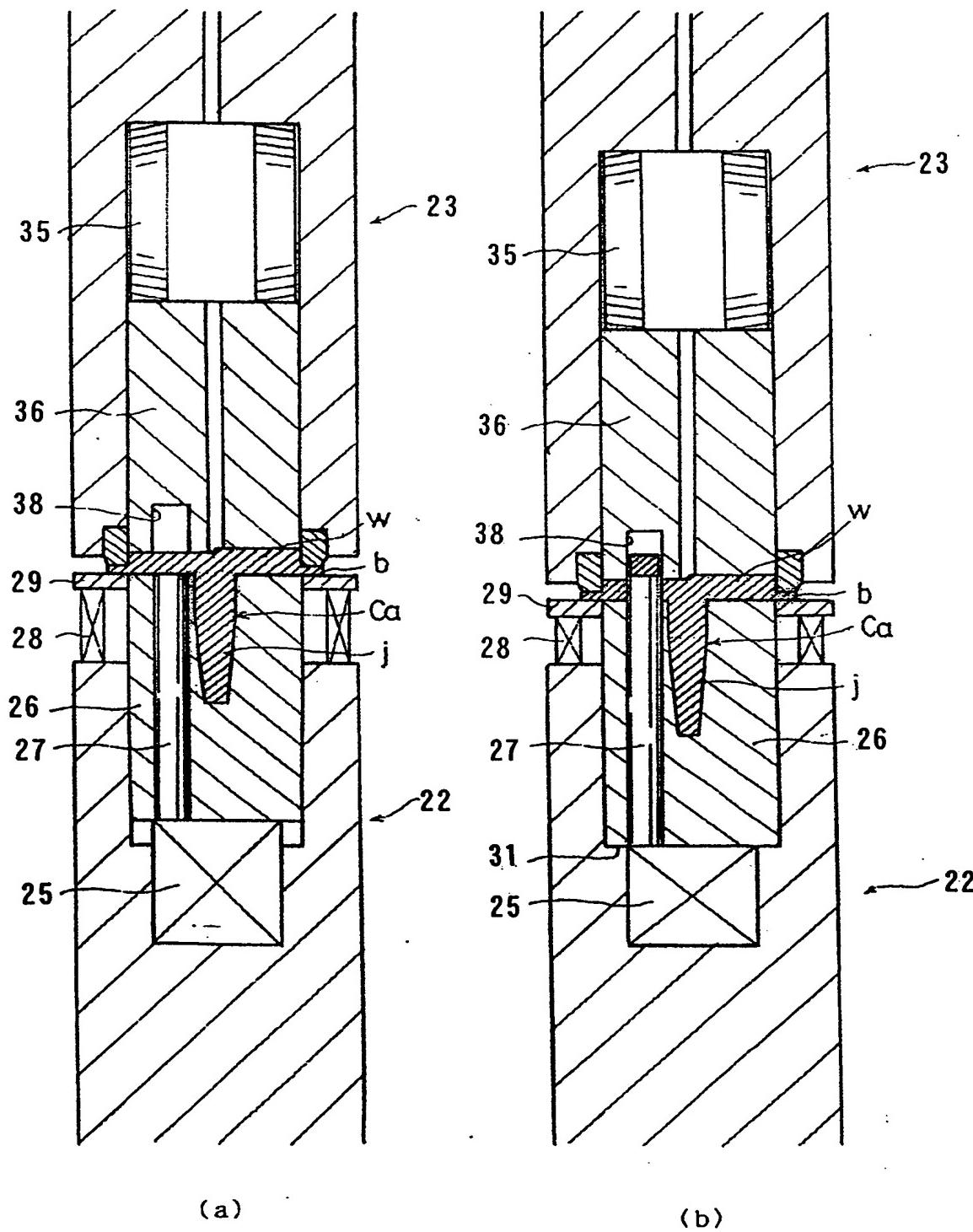


FIG. 42

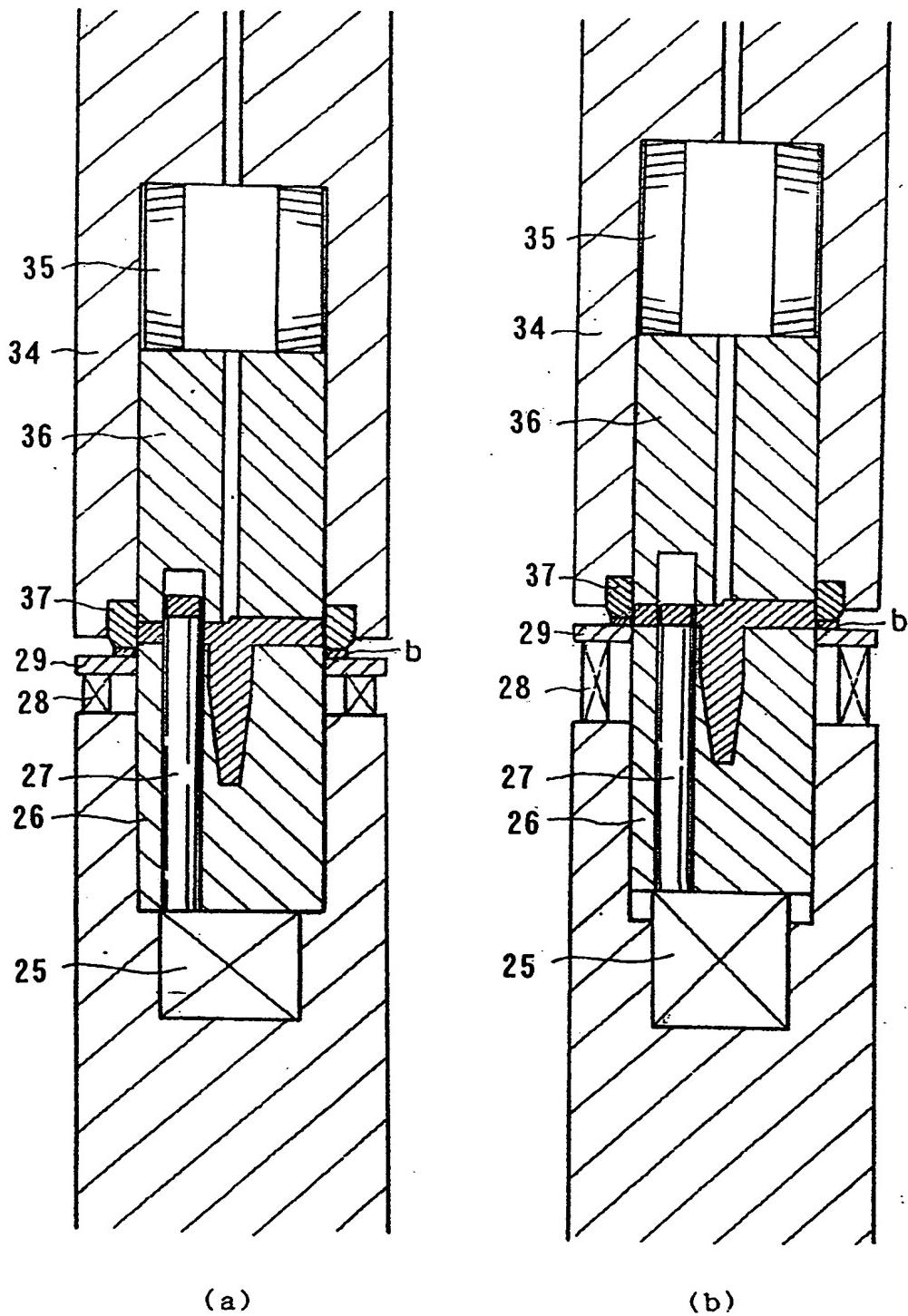
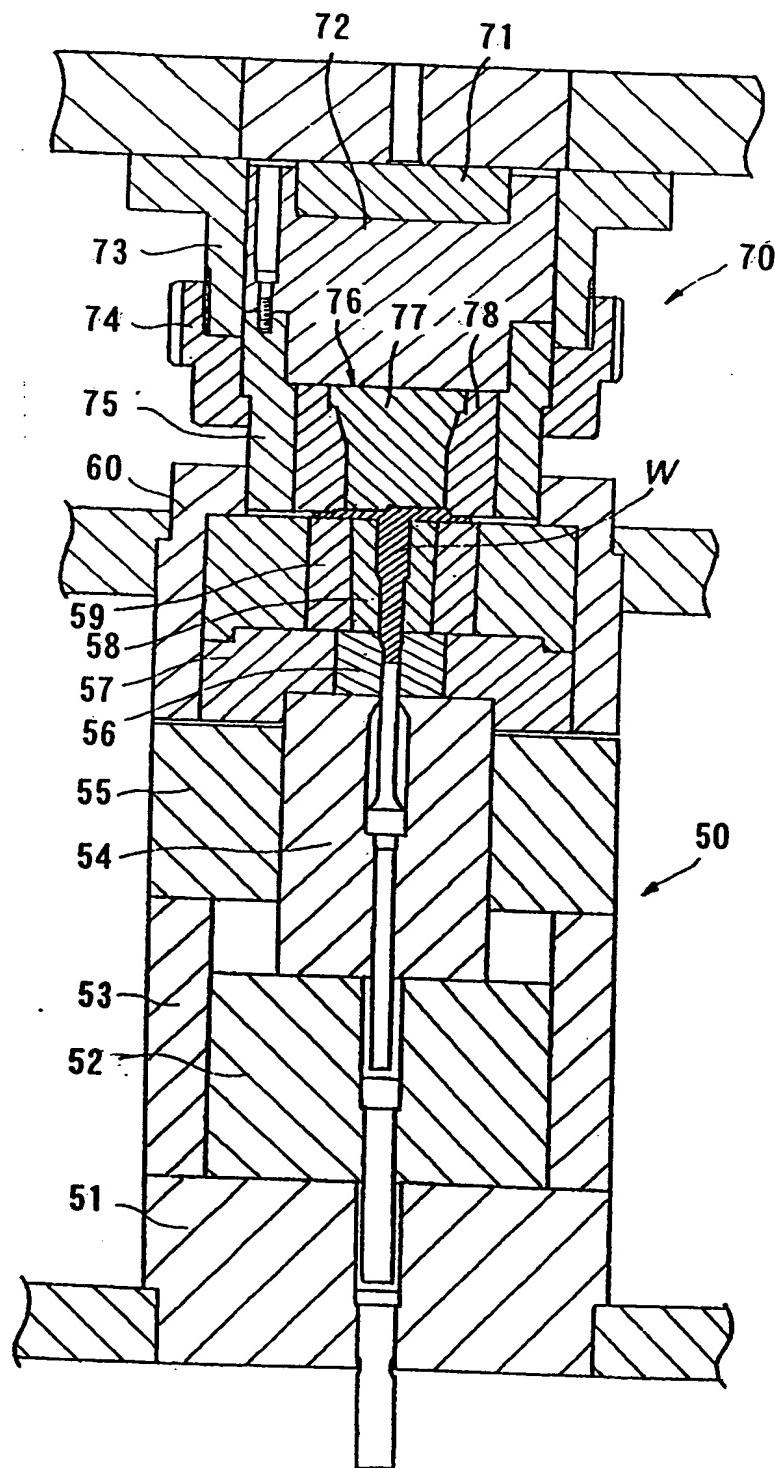


FIG. 43



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FIG. 44

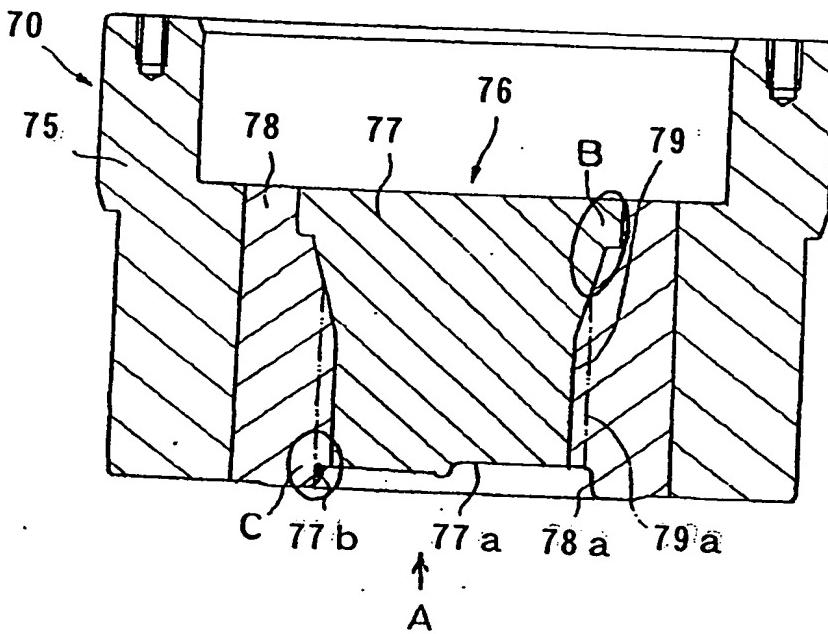


FIG. 45

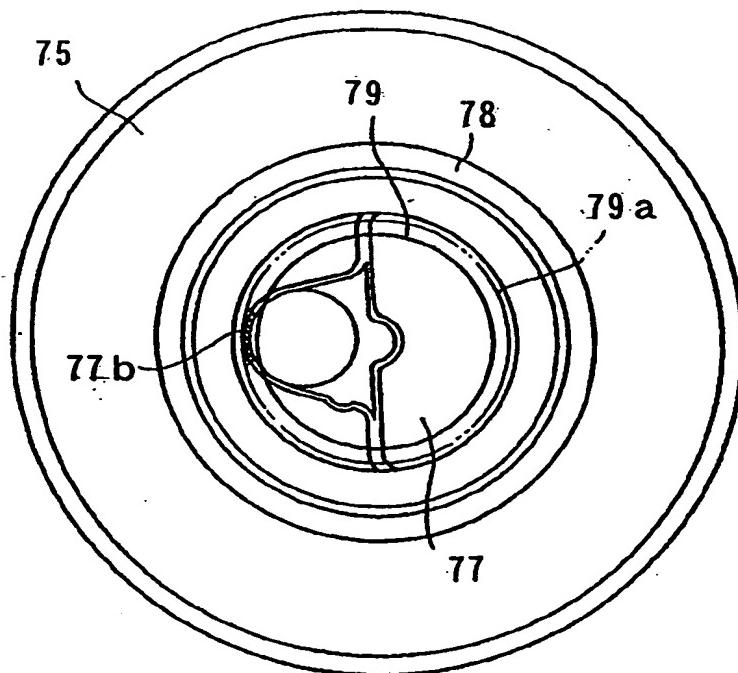


FIG. 46

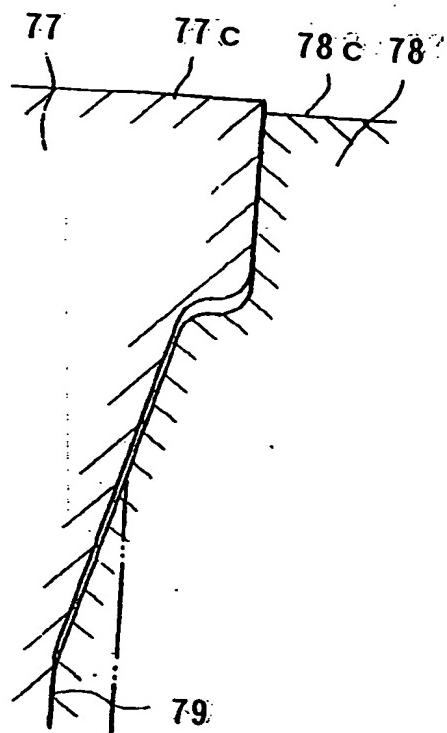


FIG. 47

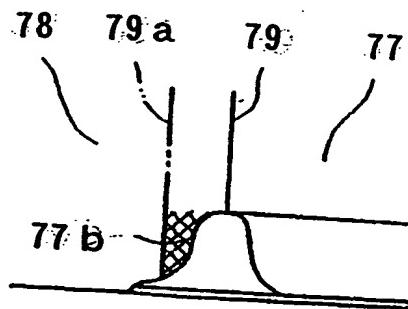


FIG. 48

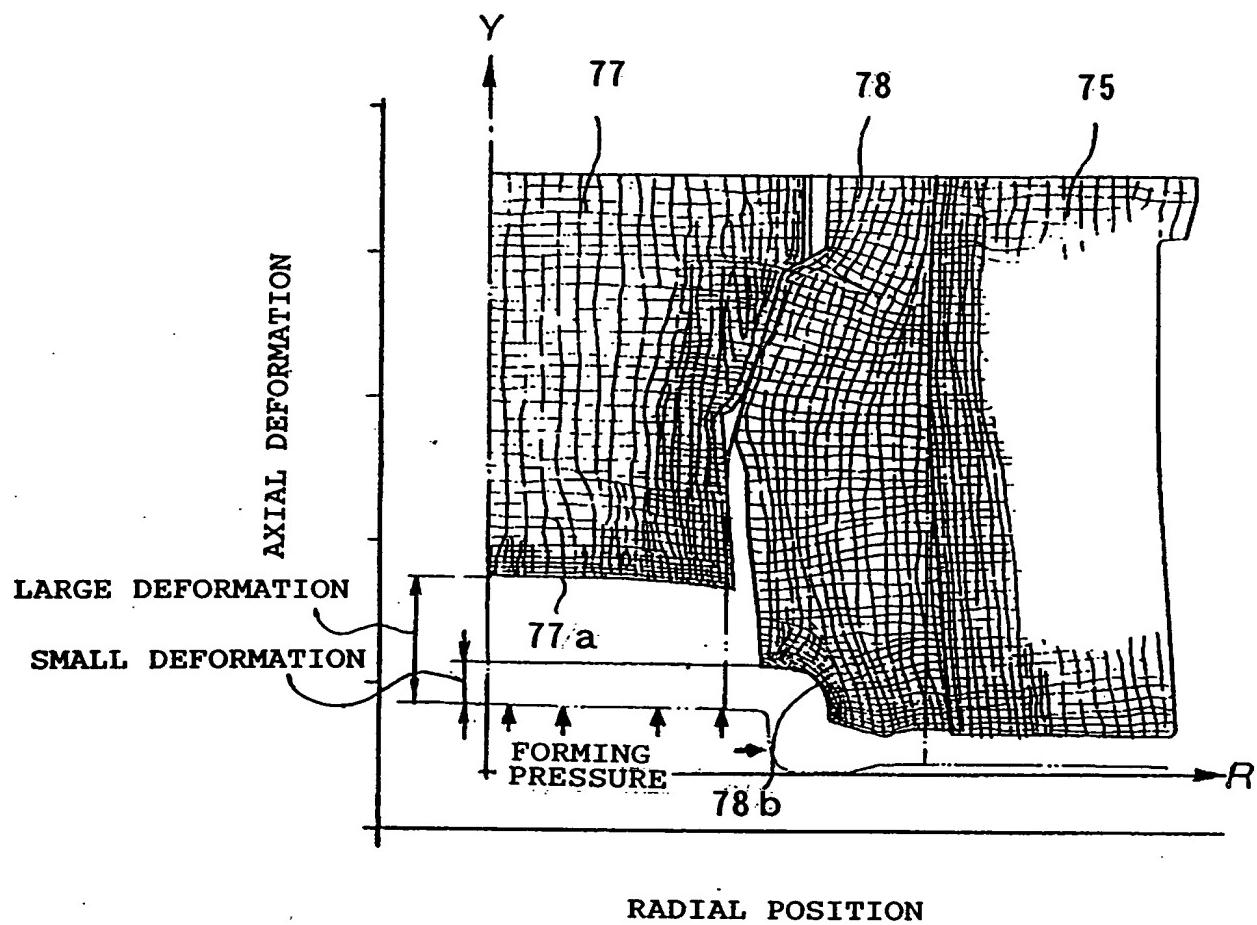


FIG. 49

	Billet manufacturing process					Aspect ratio of carbide (%)	Crack percentage % N=100
	Spherodizing annealing prior to drawing	Drawing	Cutting	Spherodizing annealing subsequent to drawing	Shot bonderizing		
Material 1	None	None	O	O	O	506	35%
Material 2	None	(20%) O	O	O	O	347	5%
Material 3	O	(20%) O	O	O	O	300	0%

$$\text{Aspect ratio (\%)} = b/a \times 100$$

